Source parameters determined using borehole recordings

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1. Rupture velocities of microearthquakes determined using stopping phases
2. Earthquake source parameters determined by the SAFOD Pilot Hole vertical seismic array

Rupture velocities of microearthquakes determined using stopping phases

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4. DPRI, Kyoto University
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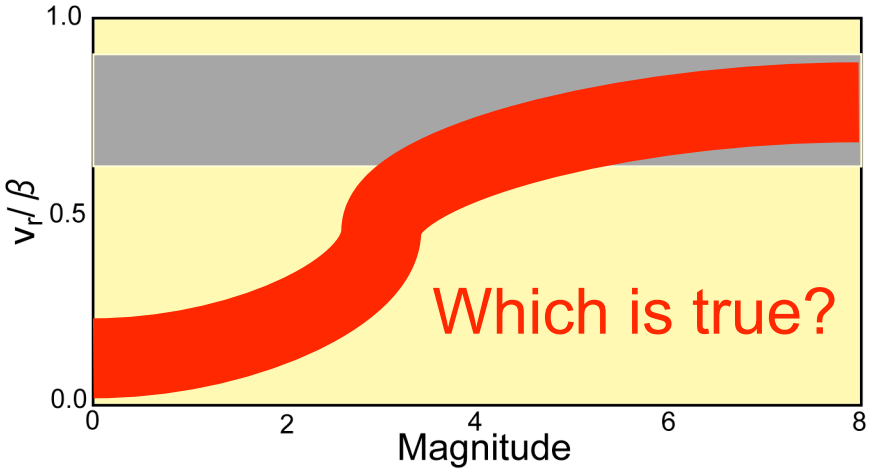
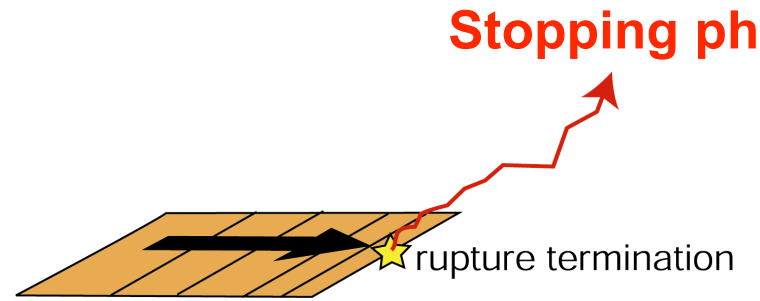
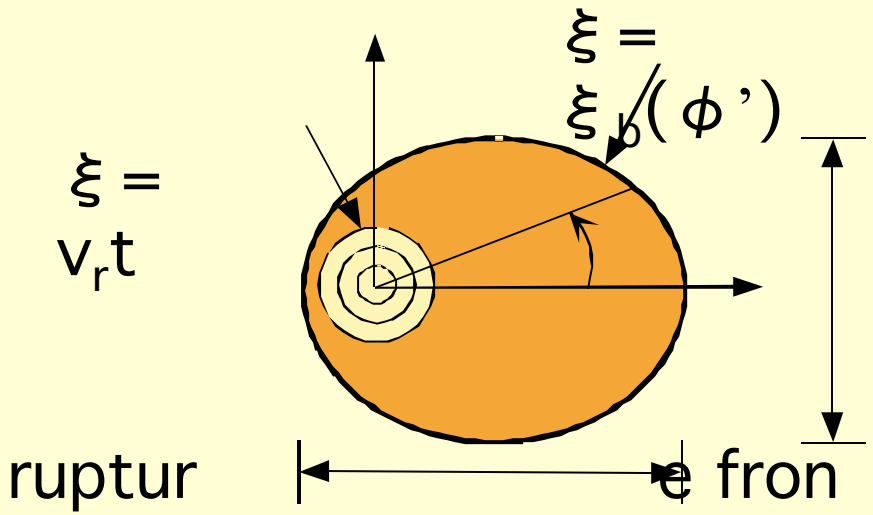
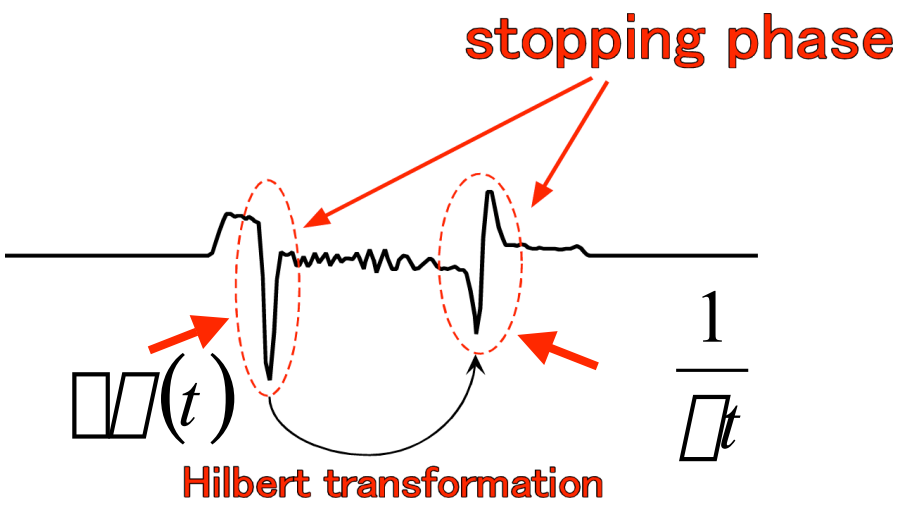

1.0
0.5
0.0
v_r/β
0
2
4
6
8
Magnitude
Which is true?


Stopping phase
rupture termination

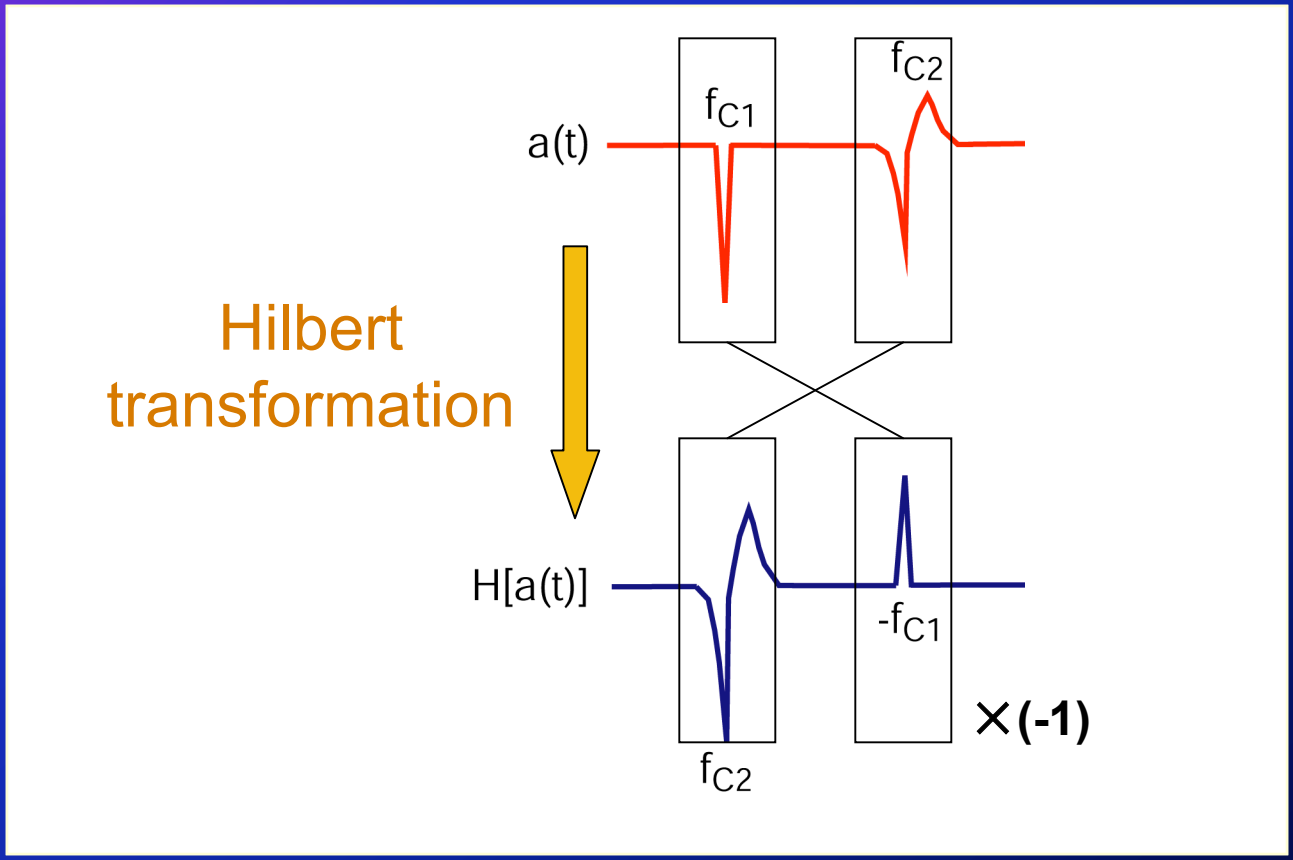
What kind of stopping phases are radiated?

Elliptical fault model
(Savage, 1966)





Mutual relation of Hilbert transform pair



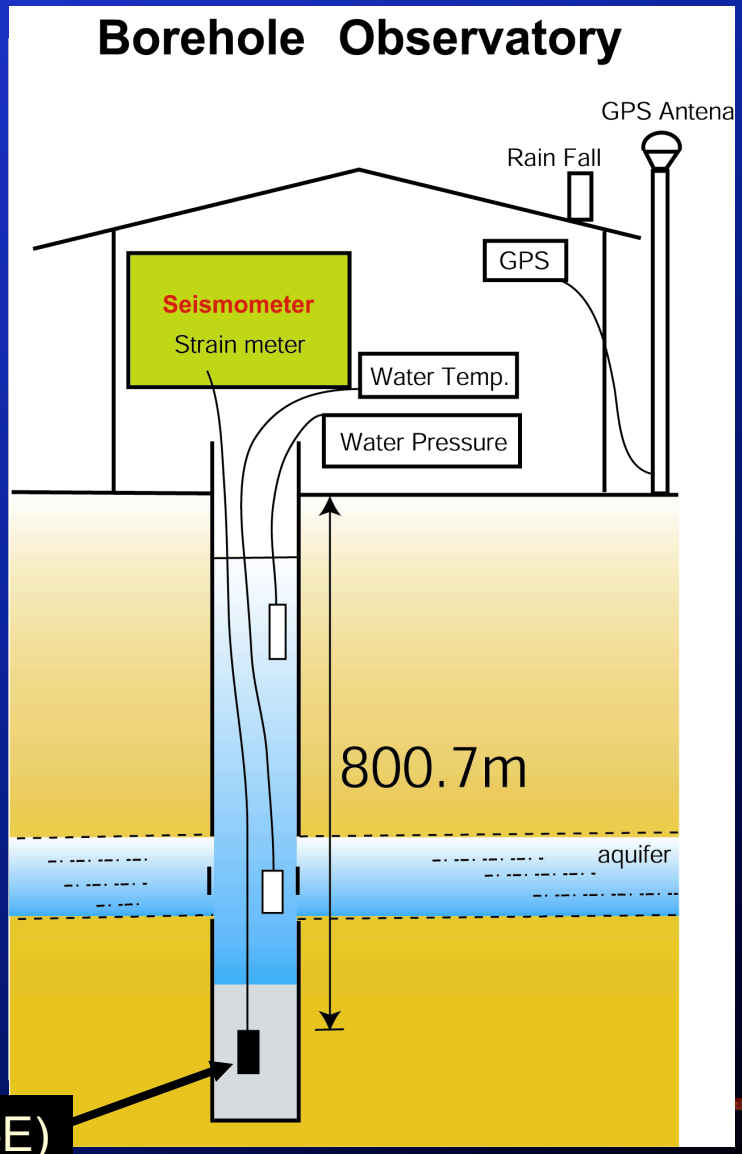
Application to data

Studied area

1.The are is characterized by persistent swarm activity.

(Most of earthquakes are less than M3.)

2. The Western Nagano earthquake (M=6.8) occurred in 1984.

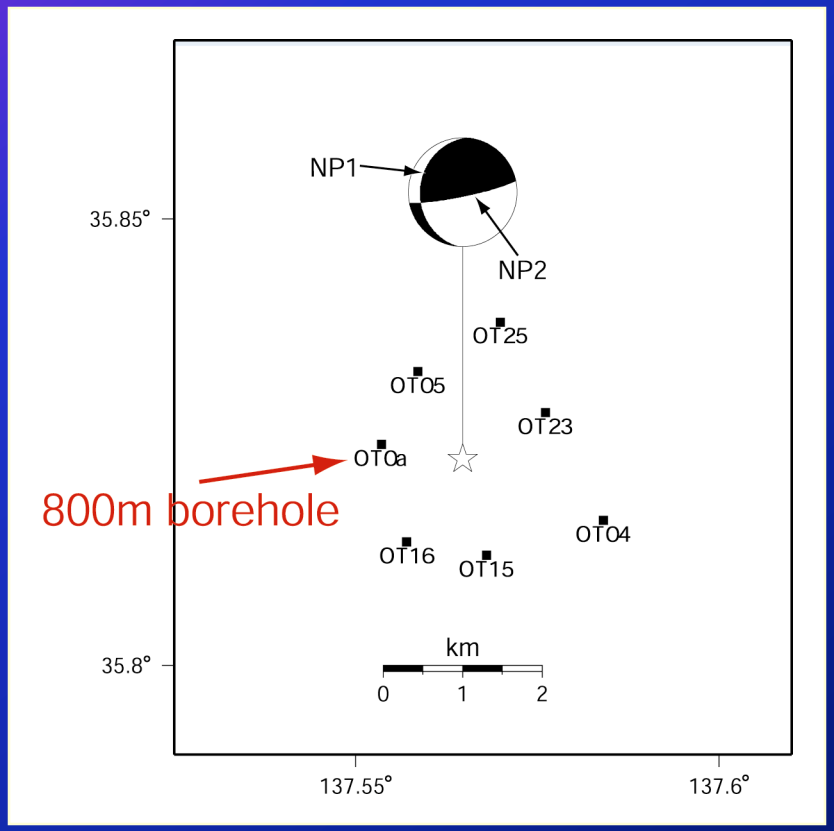


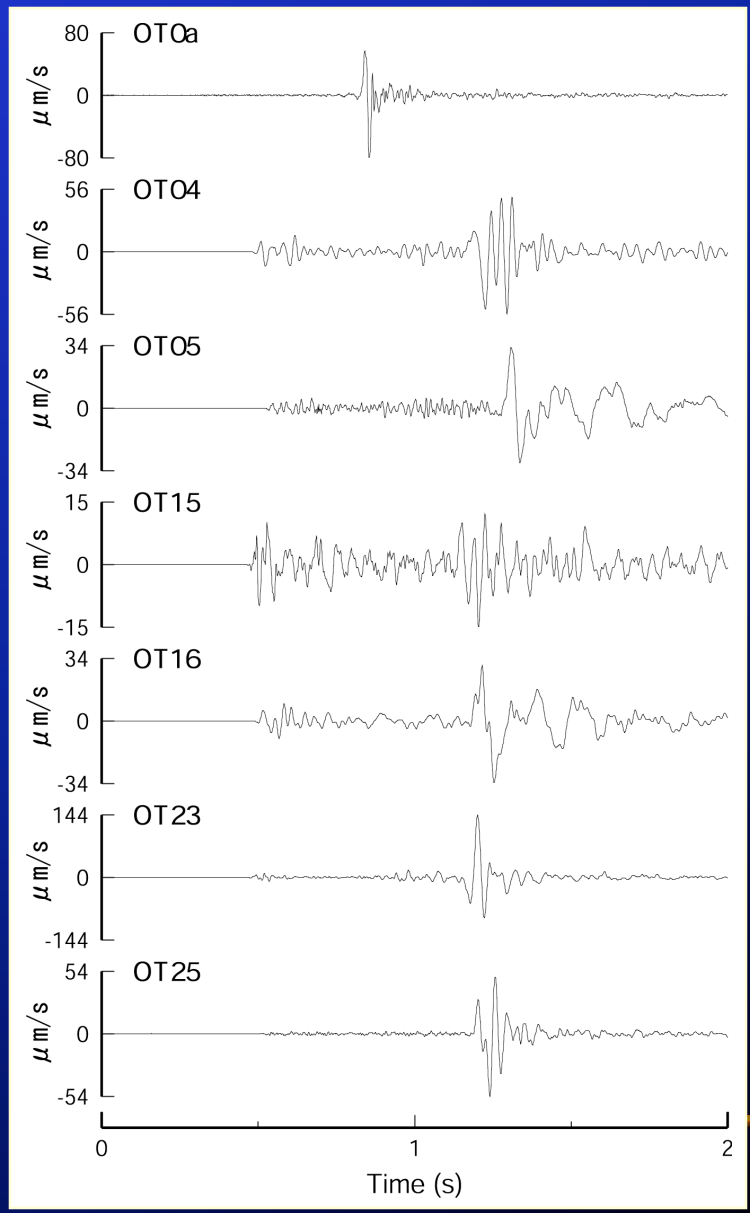
10 kHz sampling

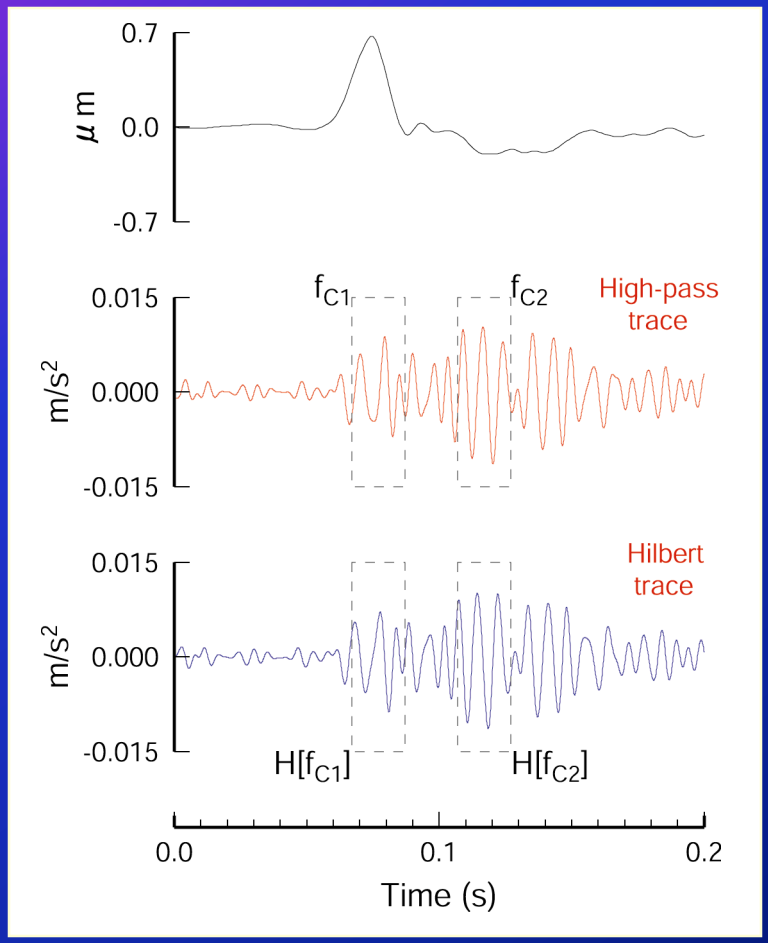
Three-component velocity transducer (L22-E)

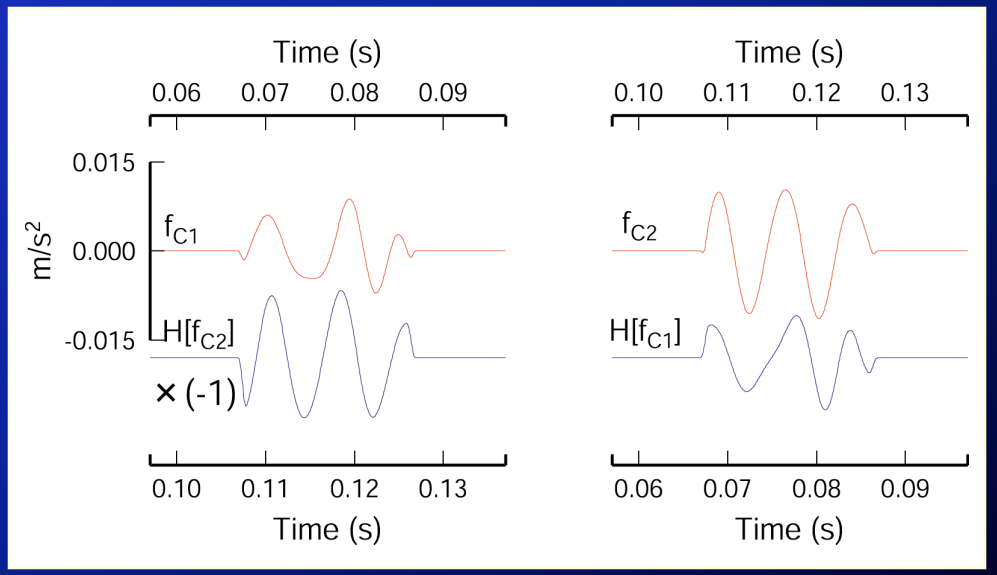
Example

M_w1.4

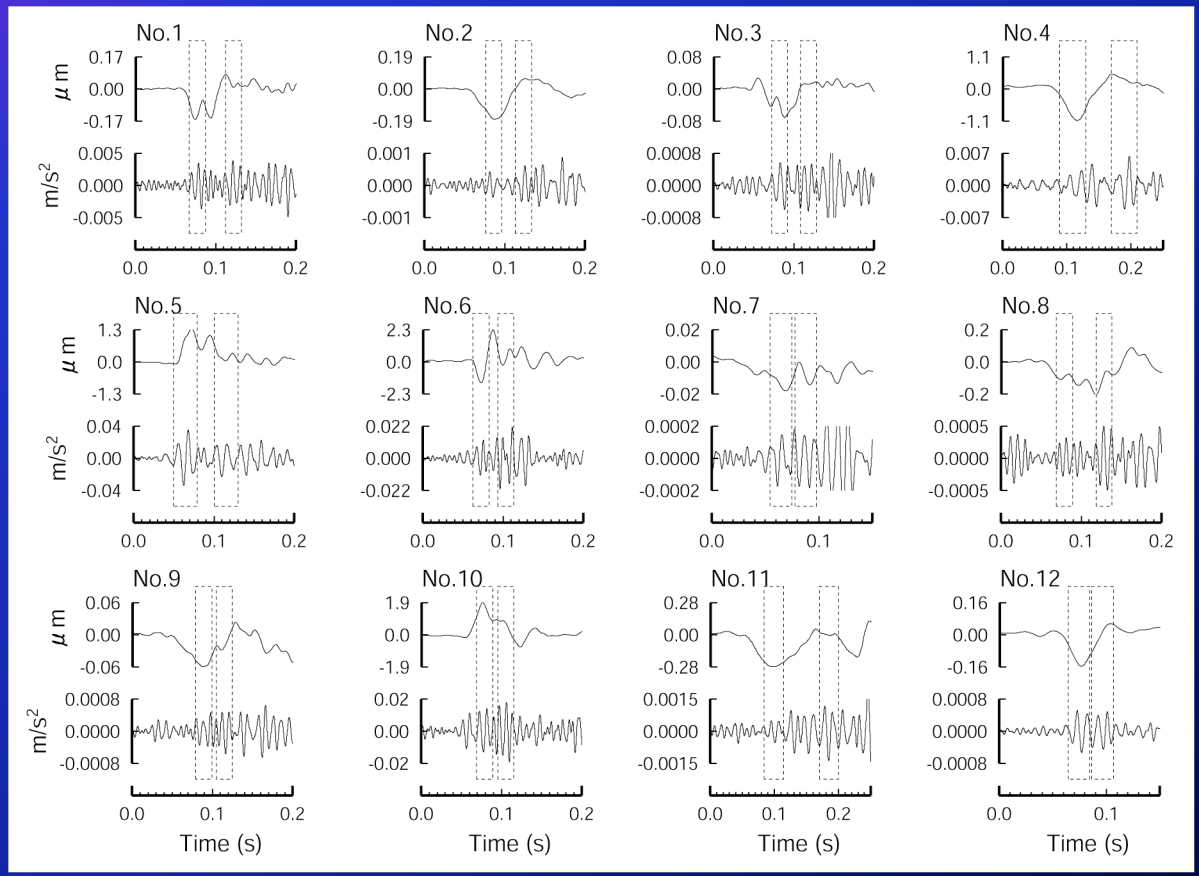





0.7
μ m
0.0
-0.7
0.015
m/s²
0.000
-0.015
f_{C1}
f_{C2}
High-pass trace
0.015
m/s²
0.000
-0.015
Hilbert trace
$H[f_{C1}]$
$H[f_{C2}]$
0.0
0.1
0.2
Time (s)


Time (s)
0.06
0.07
0.08
0.09
0.015
m/s²
0.000
-0.015
f_{C1}
$H[f_{C2}]$
× (-1)
0.10
0.11
0.12
0.13
Time (s)
Time (s)
0.10
0.11
0.12
0.13
f_{C2}
$H[f_{C1}]$
0.06
0.07
0.08
0.09
Time (s)

Other earthquakes

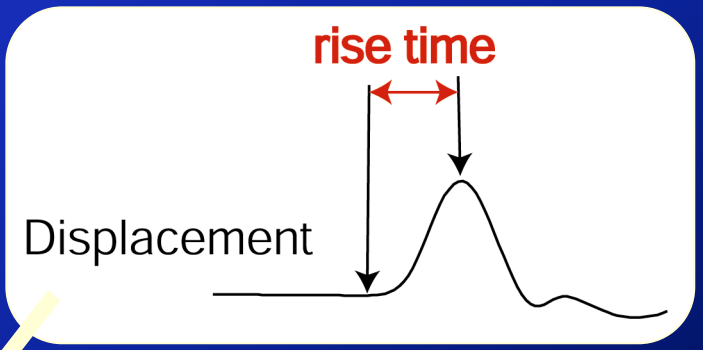


Estimation of source parameters

800m borehole station

differential time of stopping phase

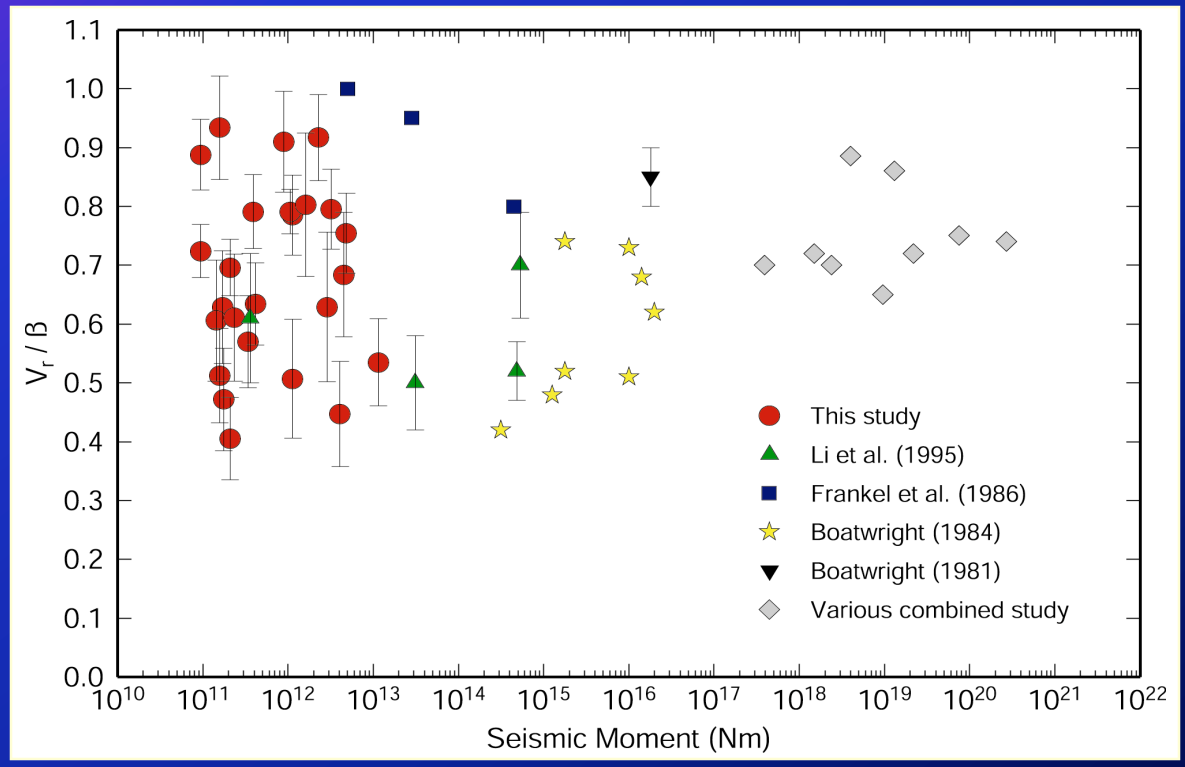
All stations



nonlinear inversion

rupture velocity, source size, rupture aspect ratio

Rupture velocity vs seismic moment



Earthquakes are self-similar over a wide range of earthquake size and the dynamics of small and large earthquakes are similar.

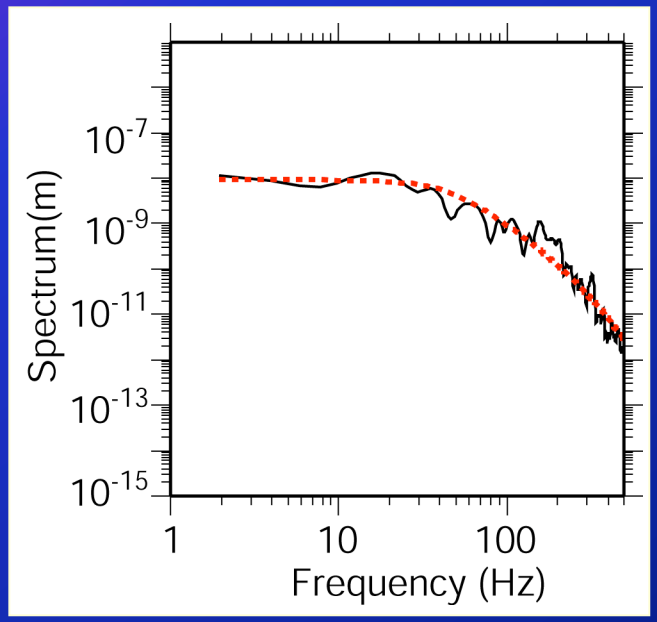
Earthquake source parameters determined by the SAFOD Pilot Hole vertical seismic array

K. Imanishi[1], W. L. Ellsworth[2] and S. G. Prejean[2]

1. Geological Survey of Japan, AIST

2. U. S. Geological Survey

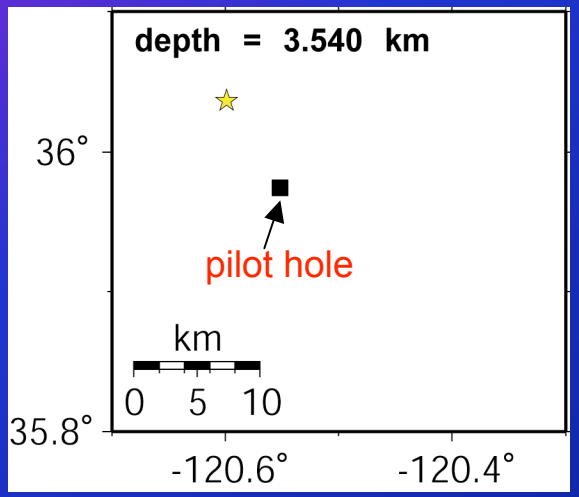
spectrum analysis

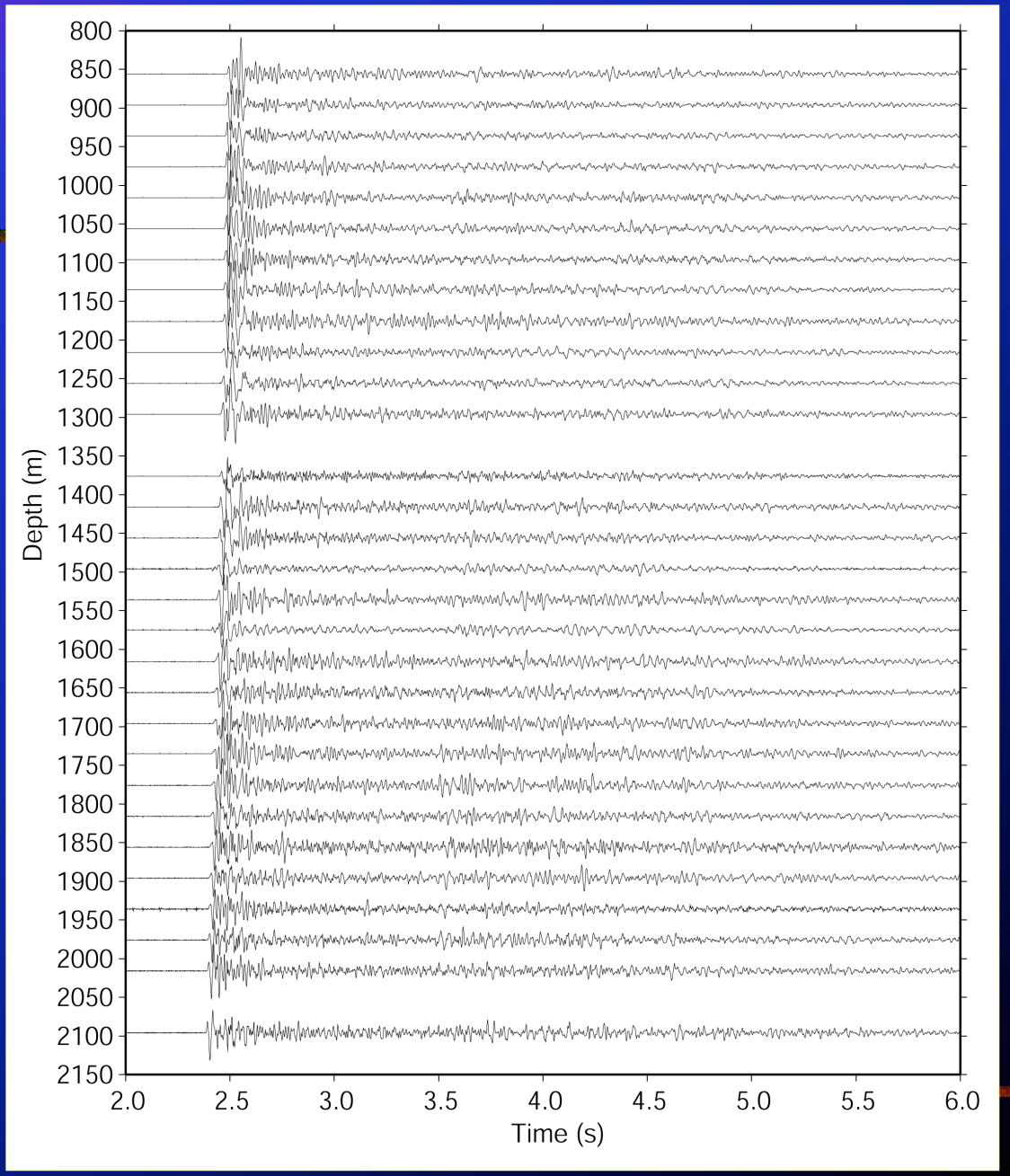


Corner frequency
Q value
Spectral level

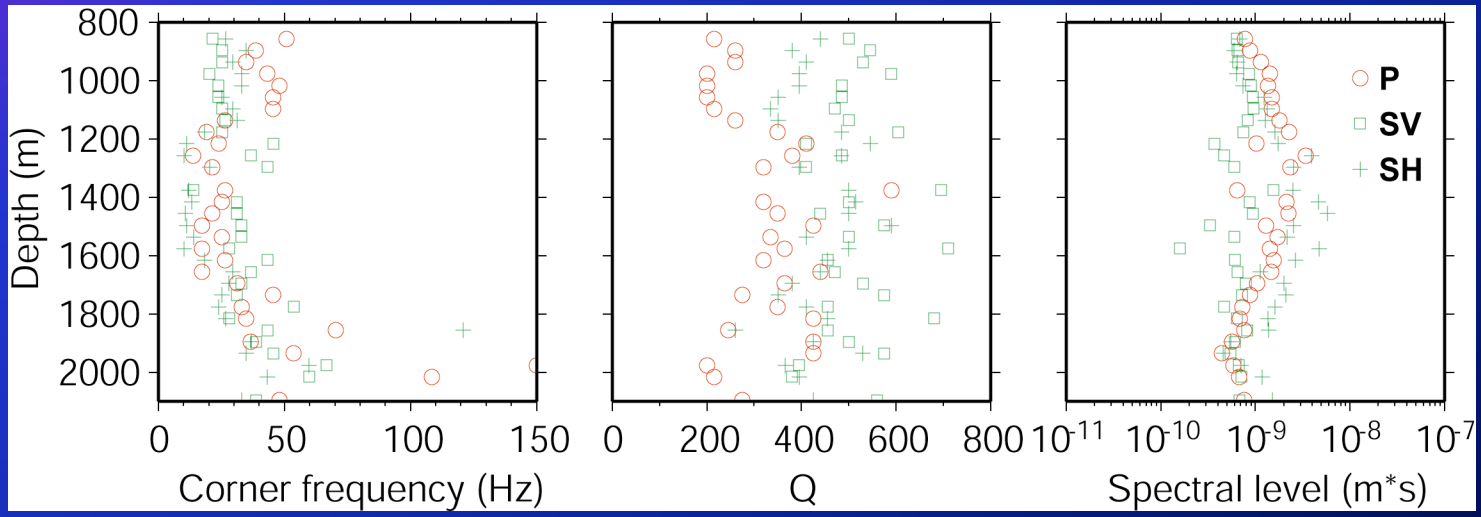
Trade-off between f_c and Q.

Example


depth = 3.540 km
36°
pilot hole
km
0 5 10
35.8°
-120.6°
-120.4°


Depth (m)
800
850
900
950
1000
1050
1100
1150
1200
1250
1300
1350
1400
1450
1500
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
2050
2100
2150
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
Time (s)

Source parameter estimations by fitting omega square model at each level.



There exists scatters in about only 1km difference of station locations.

Smoothness constraint on f_c, Q, and spectral level as a function of depth.

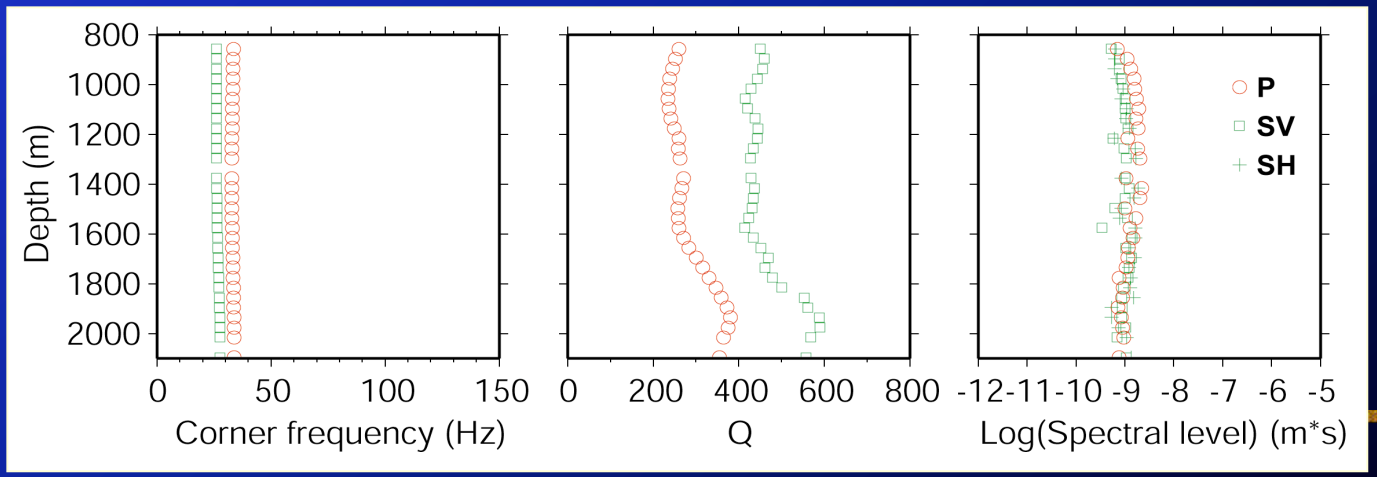
$$\left\| \frac{d - g(m)}{\sigma_d} \right\|^2 + \lambda_1 \|D_1 m\|^2 + \lambda_2 \|D_2 m\|^2 + \lambda_2 \|D_3 m\|^2 = \min.$$

d :data

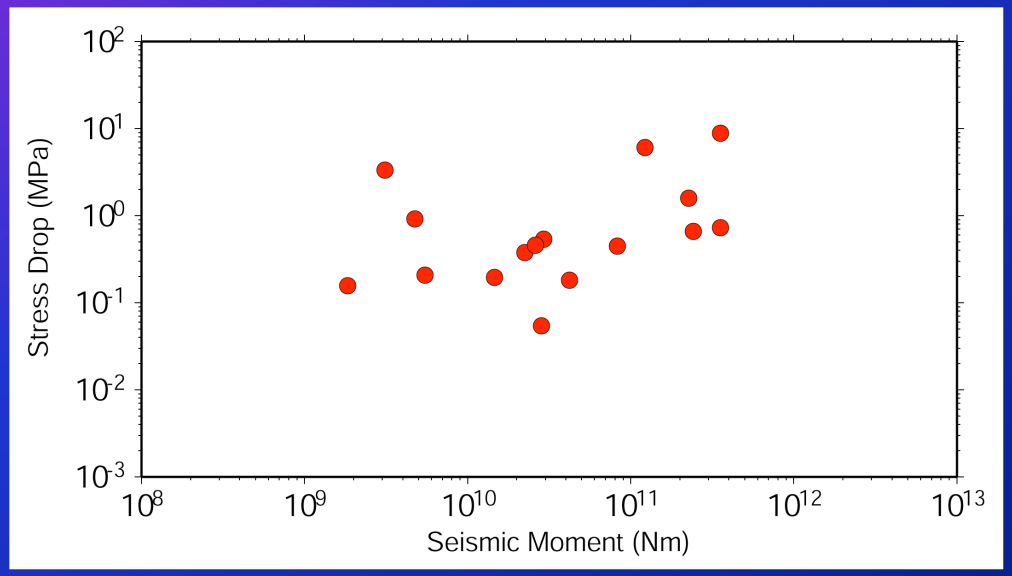
$g(m)$:omega square model

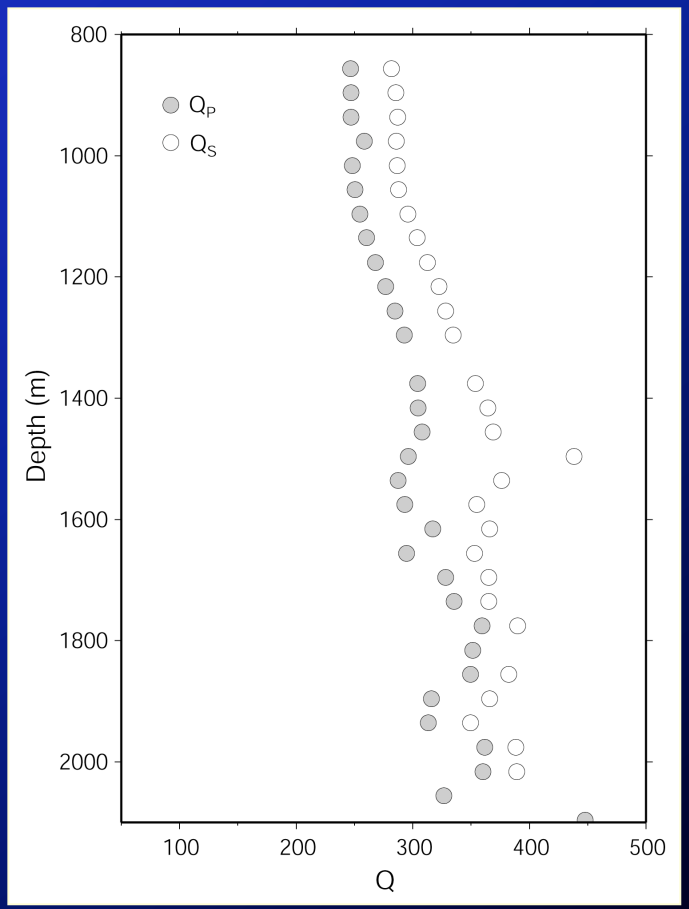
m :model parameter

D :smoothing operator



Result (Preliminary)





Vertical borehole array is a powerful tool to determine source parameters of microearthquakes.